Design and Validation of Observing System Simulation Experiments at NASA's Global Modeling and Assimilation Office

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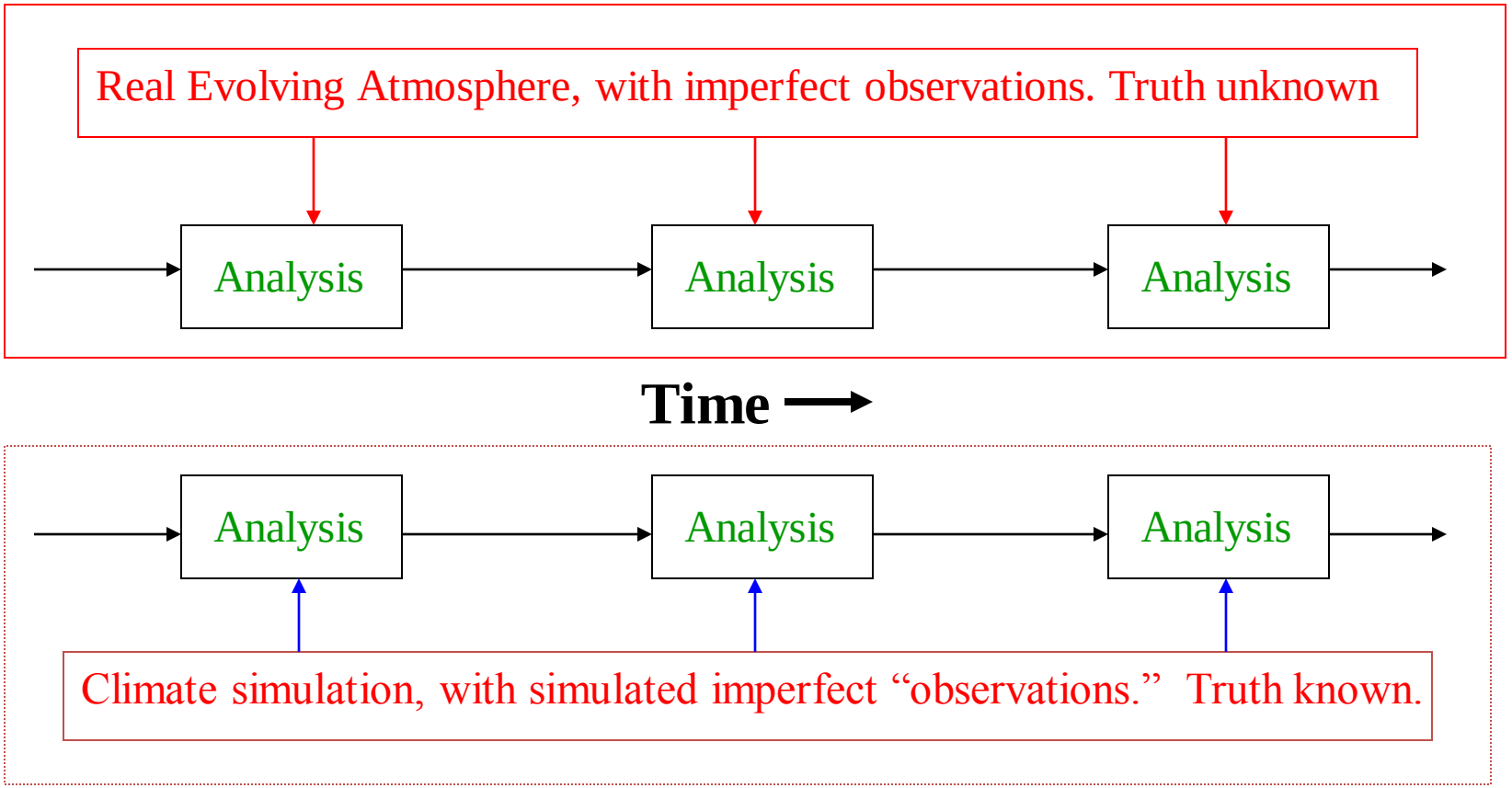
Acknowledgements

Meta Sienkiewicz
Ricardo Todling
Jing Guo
Hui-Chun Liu
Ronald Gelaro
Tong Zhu (NESDIS)
Joanna Joiner
Arlindo da Silva

Ravi Govindaraju
Will McCarty
Steve Bloom
Erik Andersson (ECMWF)
Michele Rienecker
Support from NASA and NSF

Data Assimilation of Real Data



Observing System Simulation Experiment

Applications of OSSEs

1. Estimate effects of **proposed instruments** on analysis skill by exploiting simulated environment.

2. Evaluate present and **proposed techniques** for data assimilation by exploiting known truth.

Both require an ability to simulate current observing systems

Immediate Goal

Within a short period, generate a baseline set of simulated observations and associated errors that are significantly "more realistic" than the set of baseline observations used for previously reported OSSEs.

Account for:

- Resources are somewhat limited
- The Nature Run may be unrealistic in some important ways
- Some issues are not very important compared to others
- Some important issues may still have many unknown aspects

ECMWF Nature Run

1. 13-month “forecast” starting 10 May 2005
2. Analyzed SST as lower boundary condition
3. Operational model from 2006
4. T511L91 reduced linear Gaussian grid (approx 35km)
5. 3 hourly output

NCEP/GMAO Data Assimilation System

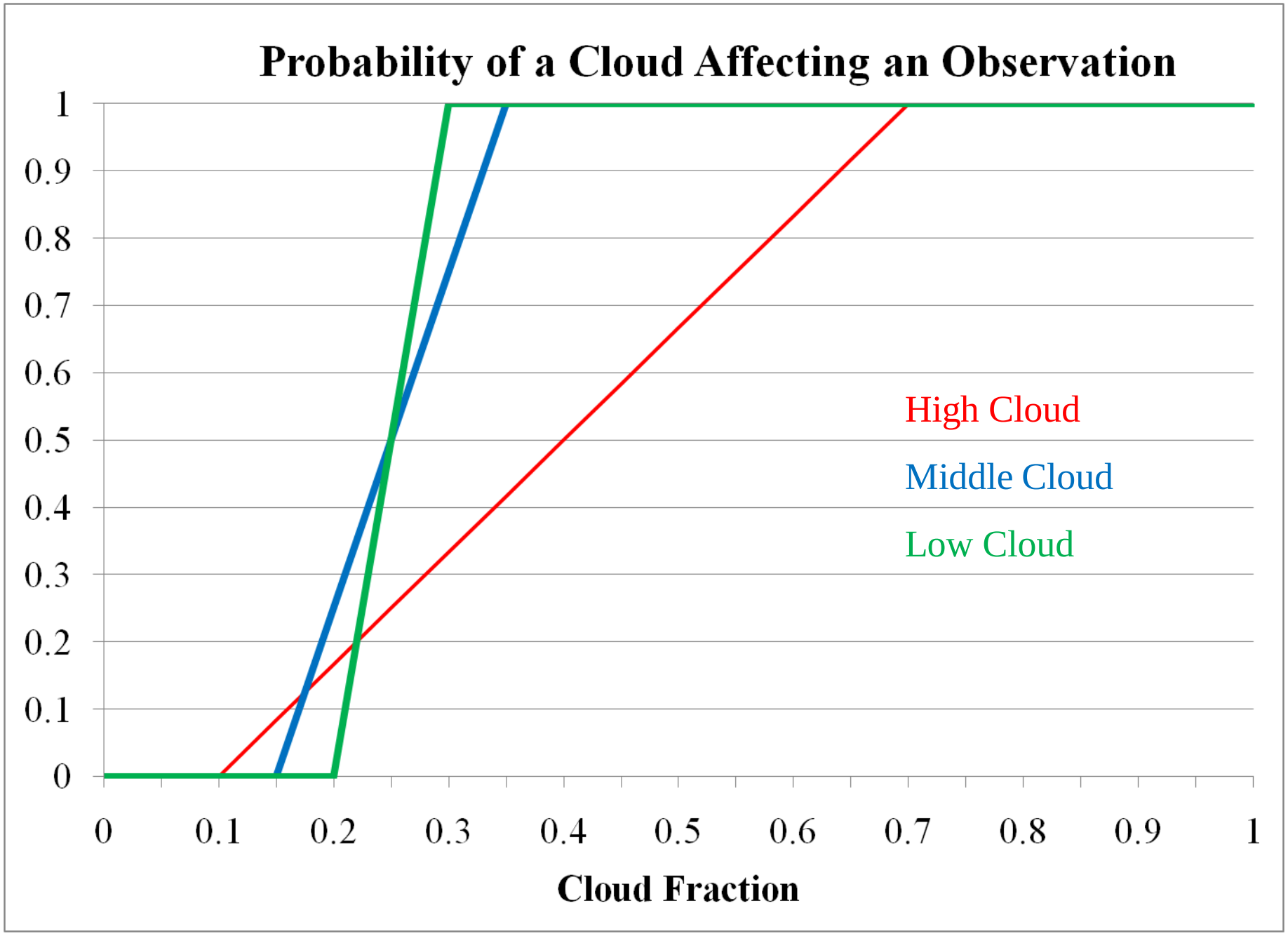
1. GSI 3DVAR every 6 hours
2. GMAO GEOS-5 forecast model with FV dynamical core
3. Resolution in current experiments: 1x1.25 degree grid, 72 levels
4. Using observation system from 2005 (except for a few types)

List of Baseline Observations for Version 1

AIRS	Soundings
AMSU-A	Radar Winds
AMSU-B	Aircraft
MSU	Surface Stations
HIRS-2/3	Sat. Tracked Winds
	Ocean surface winds

Simulation of Observations

1. Potential observation locations determined by locations of real observations
2. Partial thinning of radiance observations for computational efficiency
3. Similar JCSDA CRTMs used to both simulate and assimilate
4. Crude inclusion of cloud or precipitation contamination of radiances
5. No land- or ice-affected microwave observations simulated
6. Only locations of QC accepted conventional observations considered
7. RAOB “significant level” locations specified by real observations, not NR
8. SATWIND locations specified by real observations, not NR features
9. NR states linearly interpolated to observation locations in time and space
10. Instrument and representativeness errors added


Probability of a Cloud Affecting an Observation
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Cloud Fraction
High Cloud
Middle Cloud
Low Cloud

Evaluation of an Observing System Based on Potential Accuracy of Analyses Produced from it

Analysis accuracy depends on:

- Instrument errors
- Representativeness errors
- Extrapolation (NWP) model formulation errors
- Chaotic nature of the atmosphere and models of it

Validity of the OSSE therefore depends in large part on how well all these ERRORS are simulated.

Design of model for added observation errors
Version 1

1. Some “error” is implicitly present in the simulated observations
2. Additional error must be added explicitly
3. Added errors are drawn from random Gaussian distributions
4. No gross errors added (aside from cloud or precip. effects on rad.)
5. No biases added
6. Errors in conventional soundings are vertically correlated
7. Errors for all radiances are horizontally correlated (no channel correl.)
8. Errors in SATWINDS for geo-stationary obs. horizontally correlated
9. Error variances are between 0.6 and 1 of GSI specified R values
10. No attempt yet to fine tune the added error variances

Validation

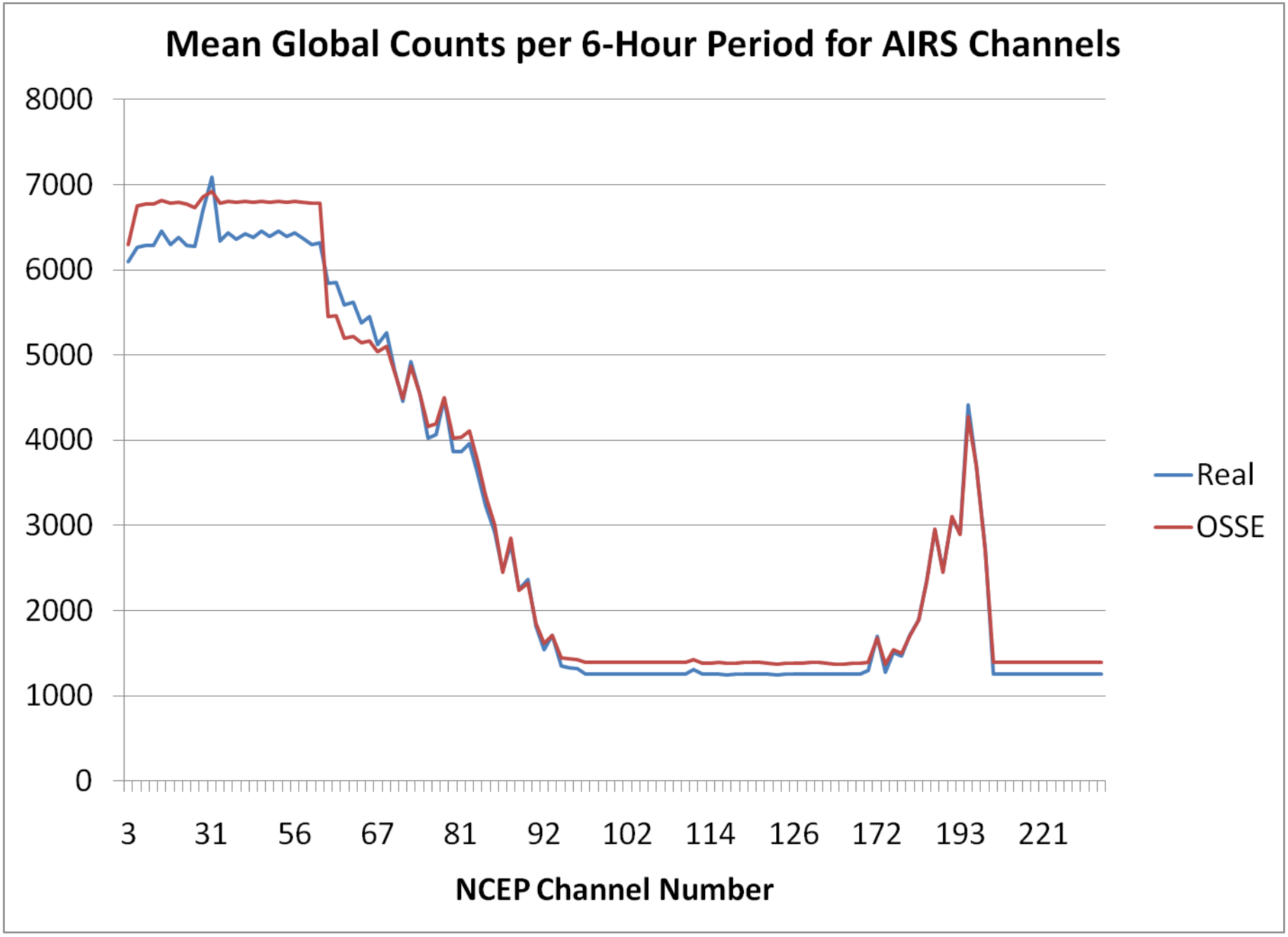
Compare results from 2 GSI runs: The OSSE uses simulated observations; the other uses real observations.

The same observation error statistics are used for both GSI runs.

Both begin in early December 2005 to provide month-long spin-up.

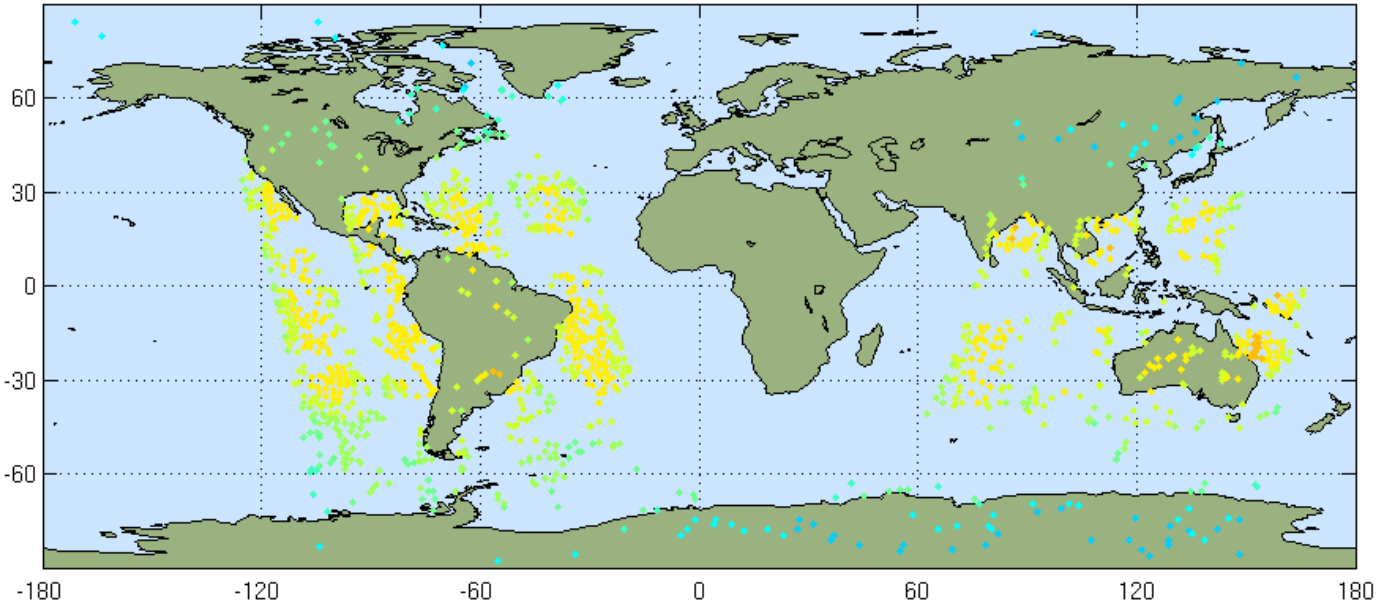
Radiance bias correction coefficients for the OSSE run are initialized to 0.

Statistics are examined for the full month of January 2006.

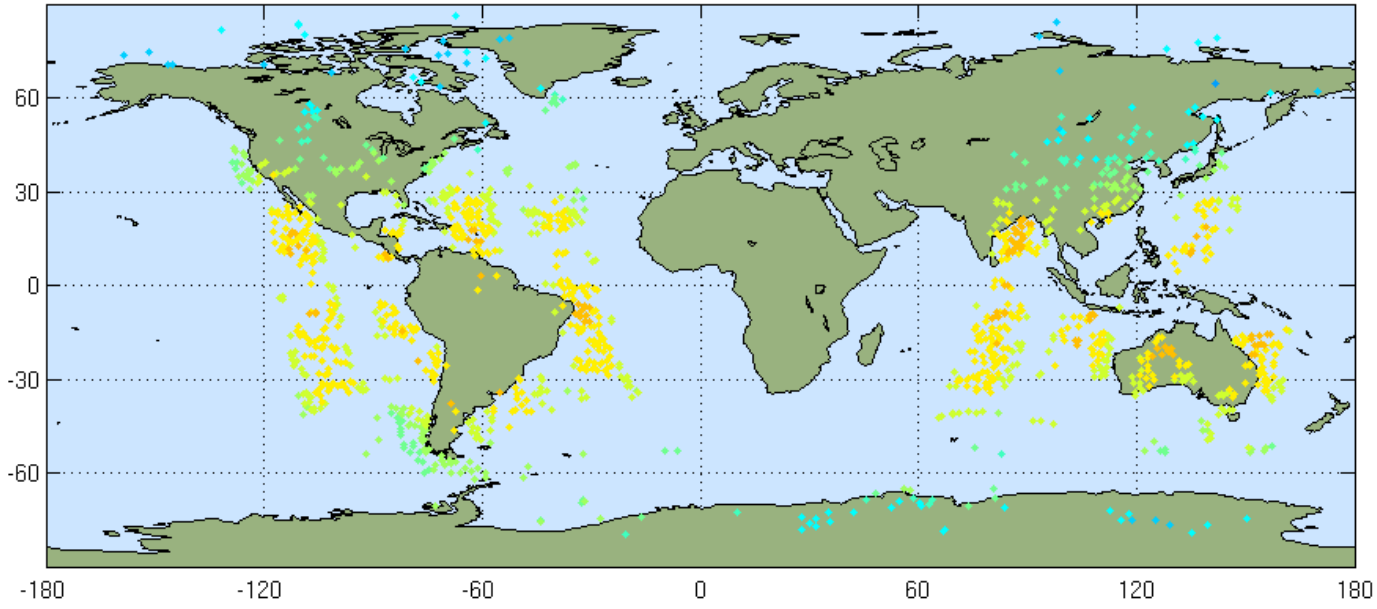

Mean Global Counts per 6-Hour Period for AIRS Channels
8000
7000
6000
5000
4000
3000
2000
1000
0
3
31
56
67
81
92
102
114
126
172
193
221
NCEP Channel Number
Real
OSSE

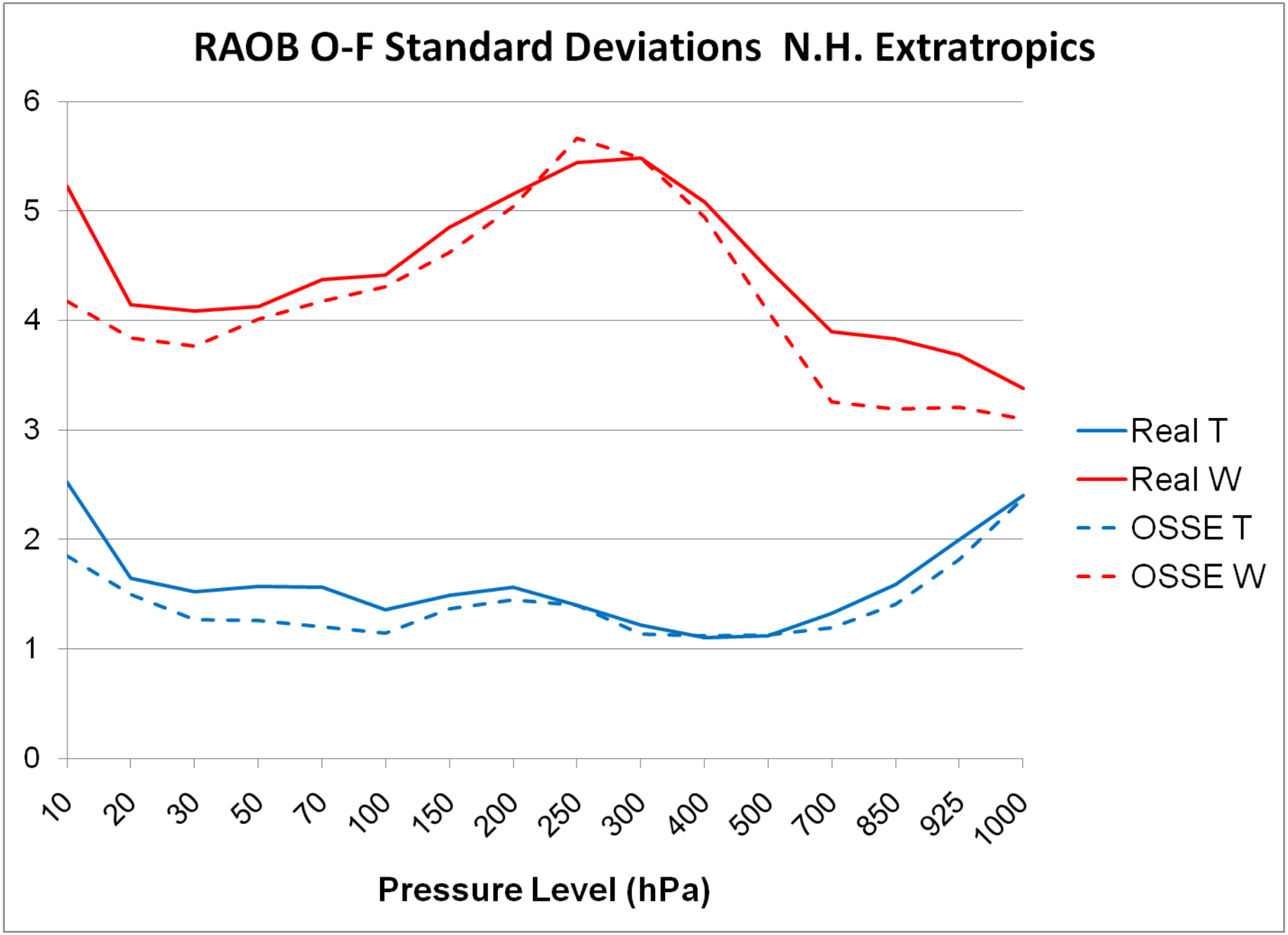
Quality Accepted Observation Locations for NCEP Channel 106 AIRS AQUA 4 Jan 2006 18UTC

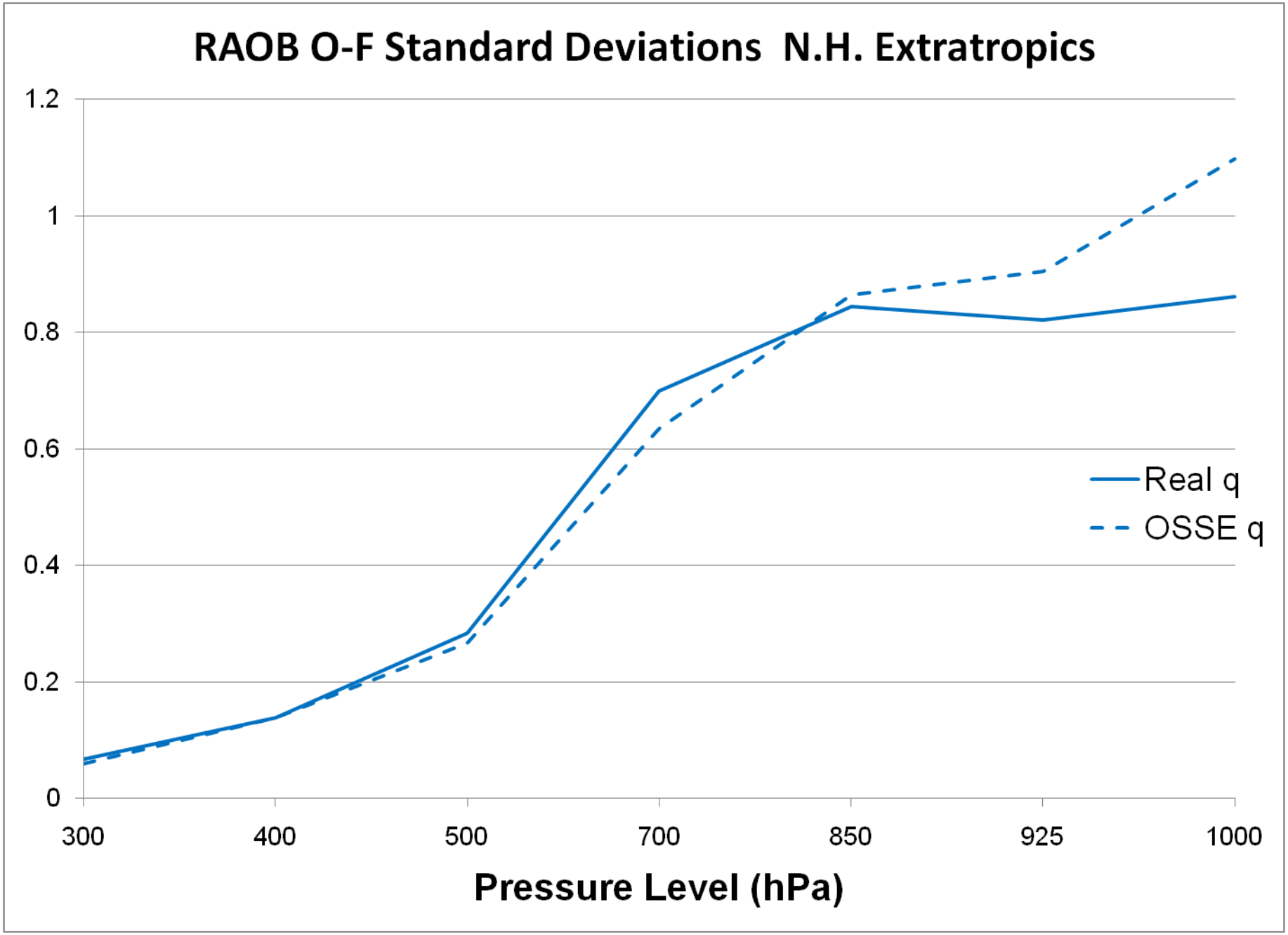
Real Observations
Count=1307

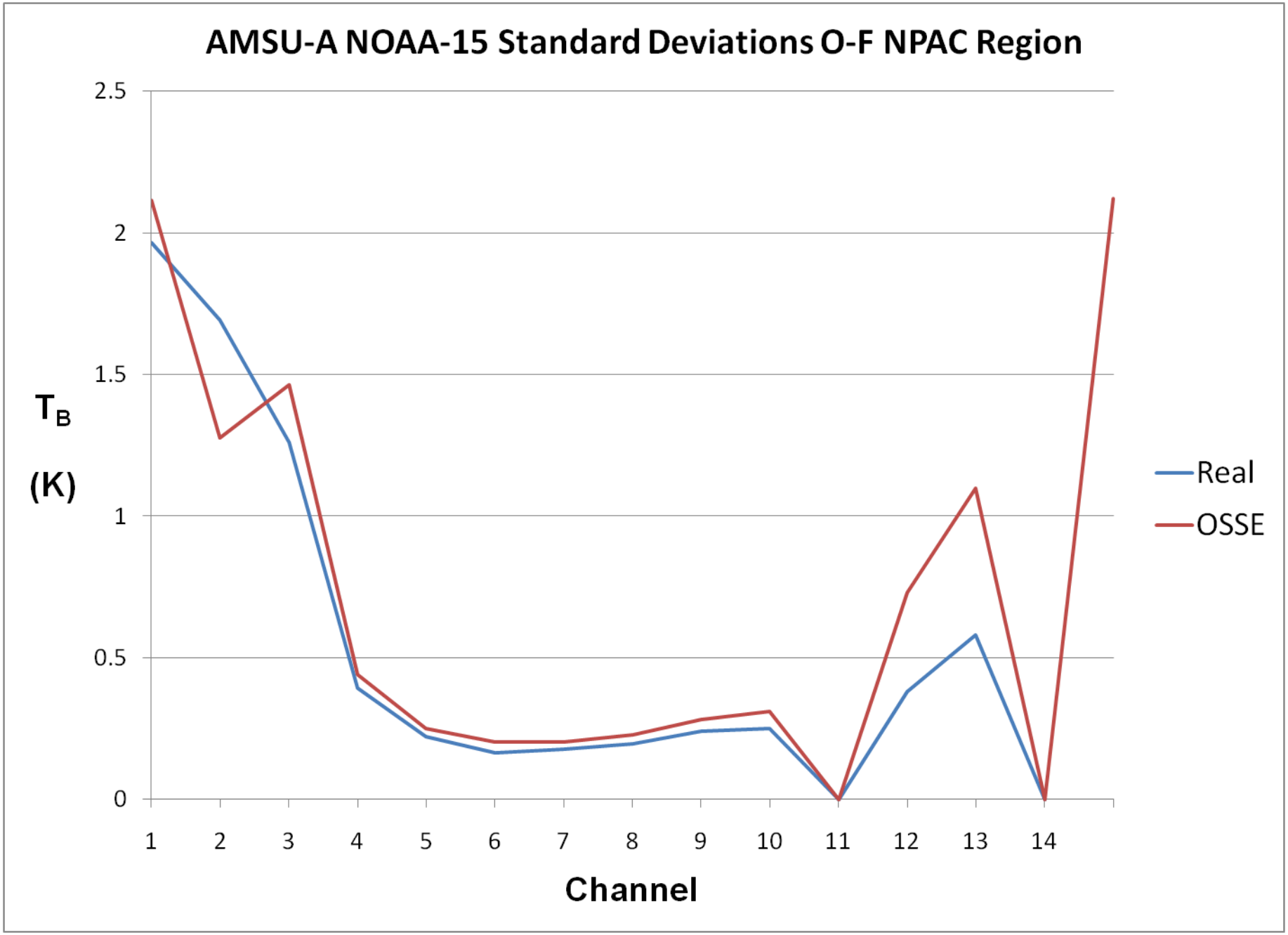


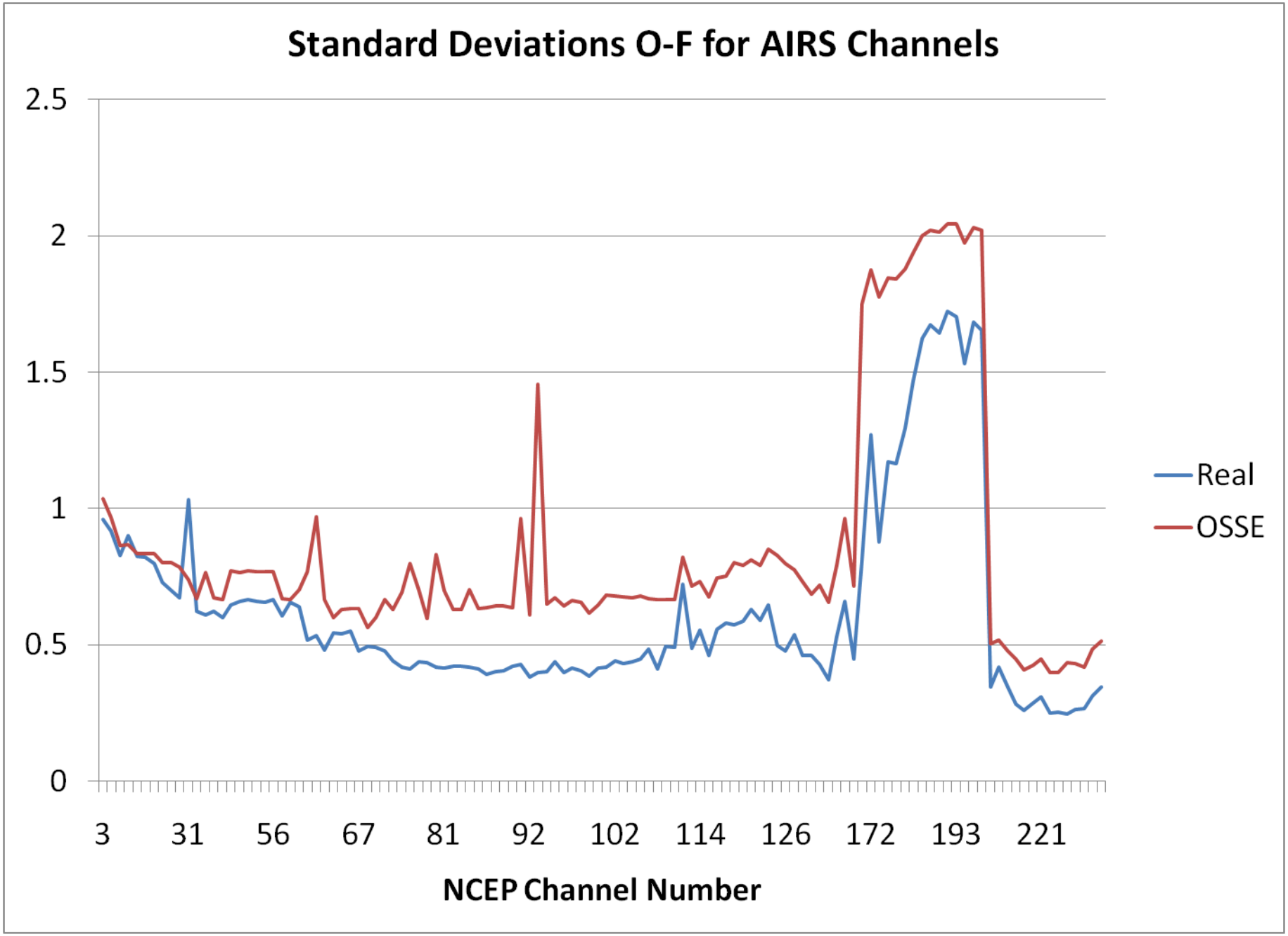
OSSE Observations
Count=1229

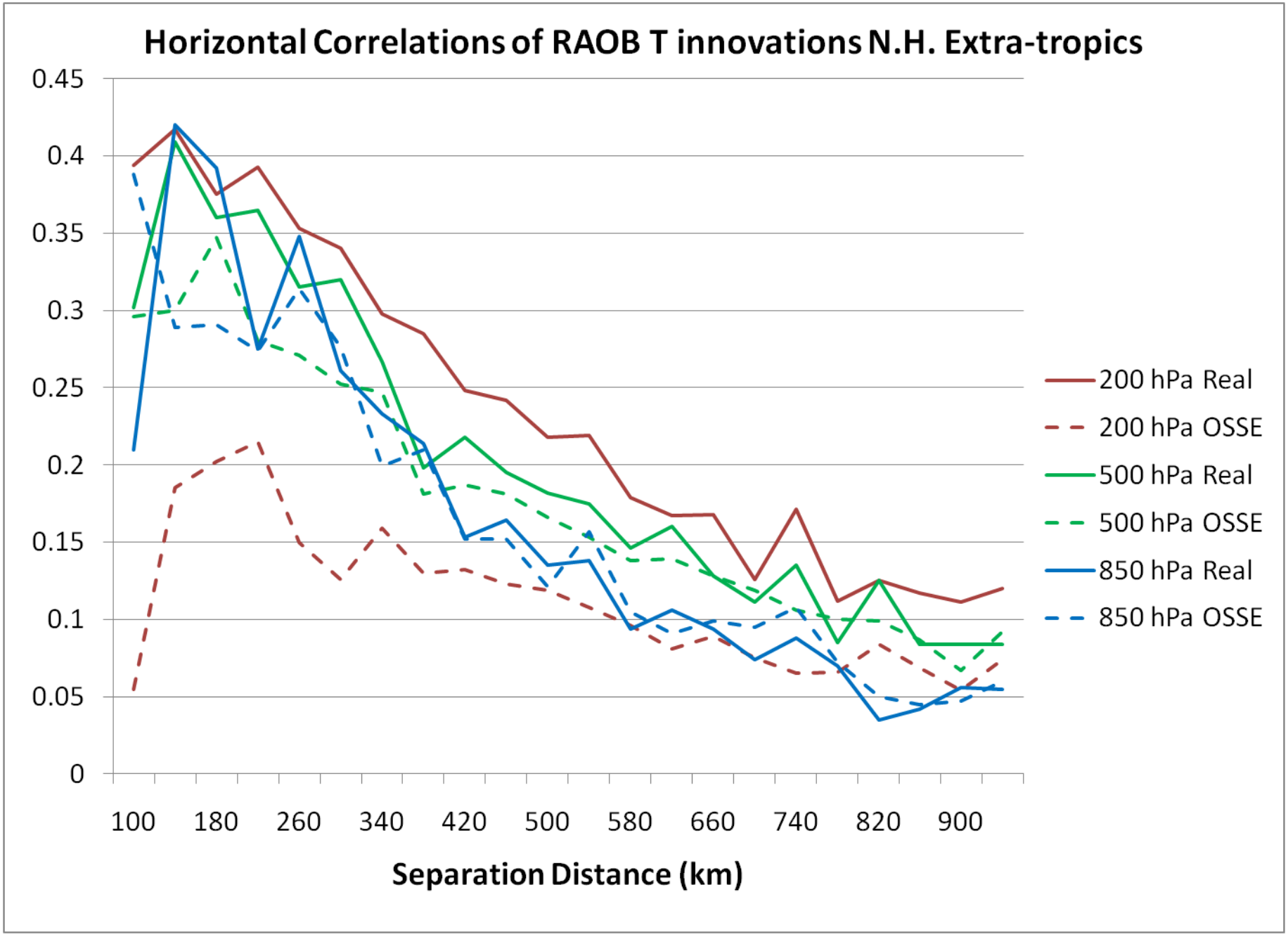


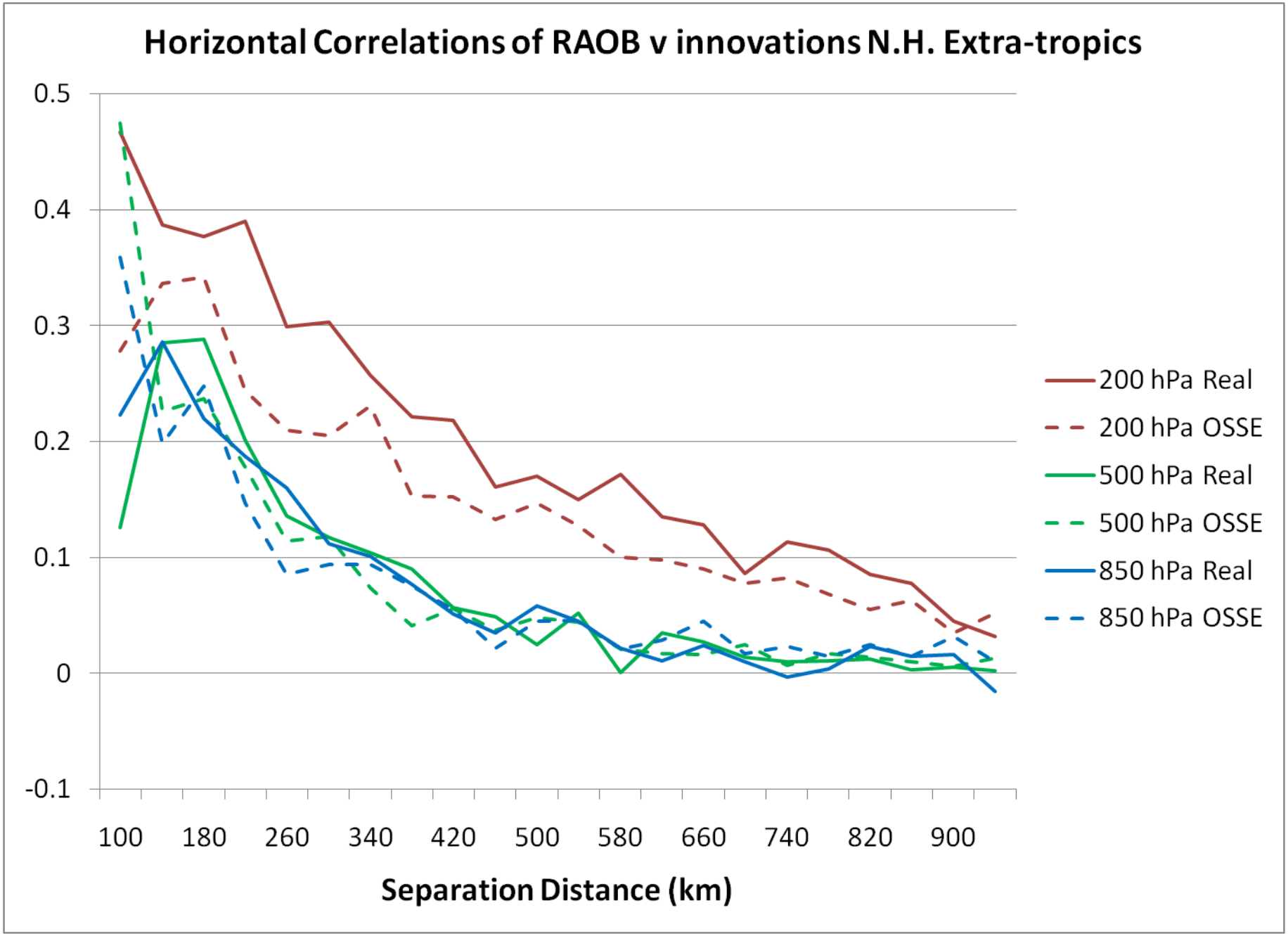

RAOB O-F Standard Deviations N.H. Extratropics
6
5
4
3
2
1
0
10
20
30
50
70
100
150
200
250
300
400
500
700
850
925
1000
Pressure Level (hPa)
Real T
Real W
OSSE T
OSSE W

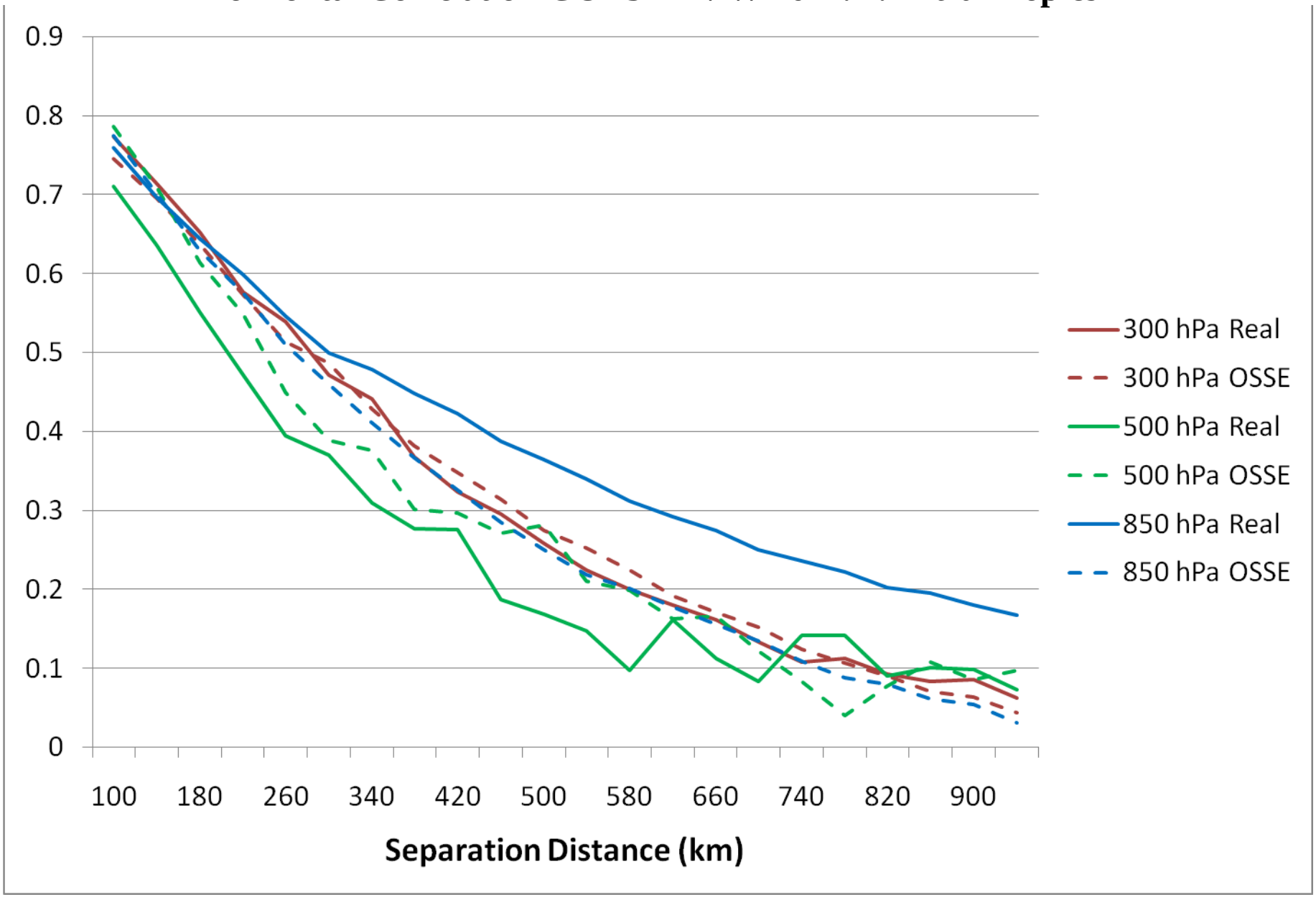

RAOB O-F Standard Deviations N.H. Extratropics
1.2
1
0.8
0.6
0.4
0.2
0
300
400
500
700
850
925
1000
Pressure Level (hPa)
Real q
OSSE q

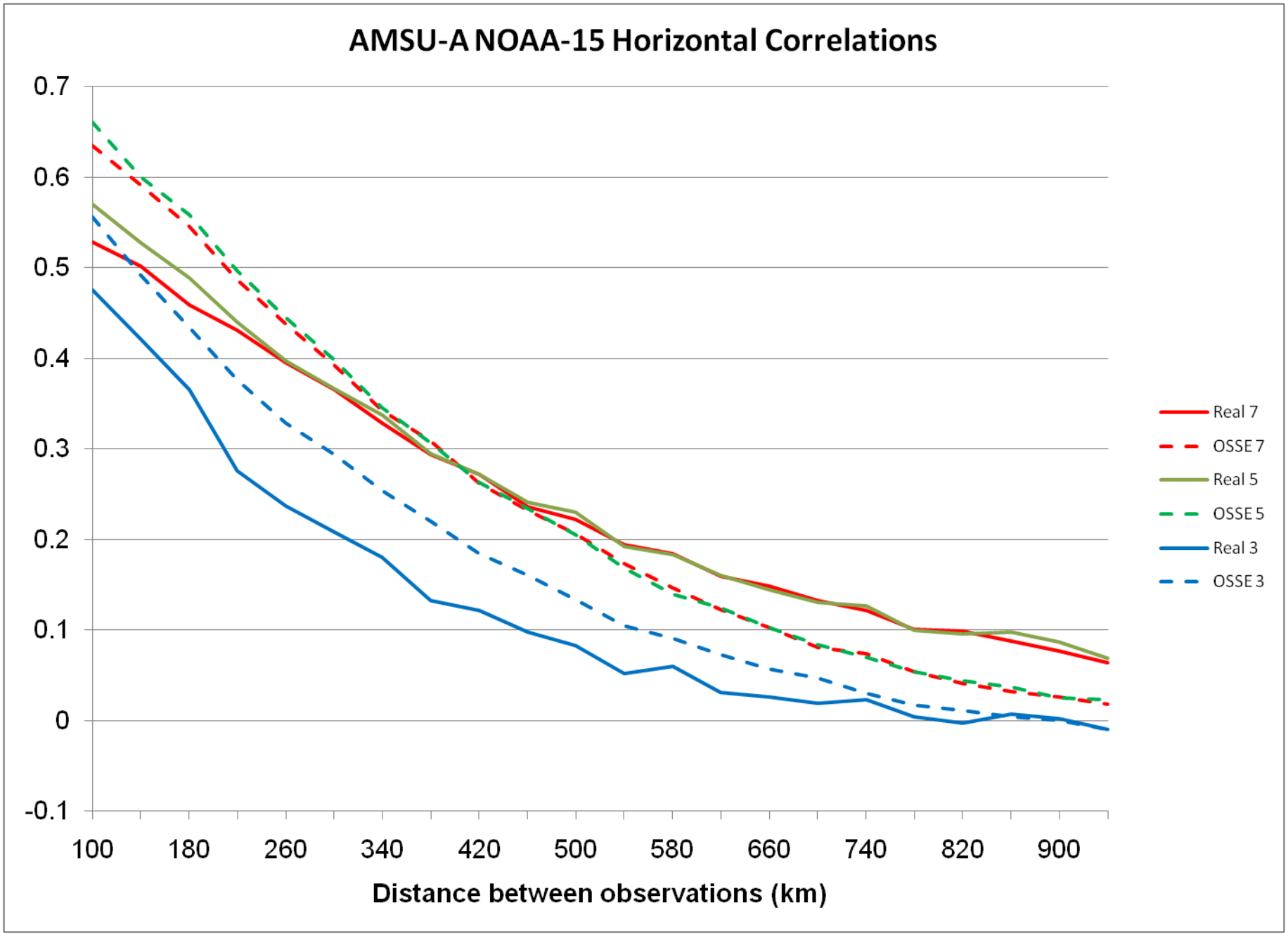

AMSU-A NOAA-15 Standard Deviations O-F NPAC Region
2.5
2
1.5
1
0.5
0
T_B
(K)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Channel
Real
OSSE

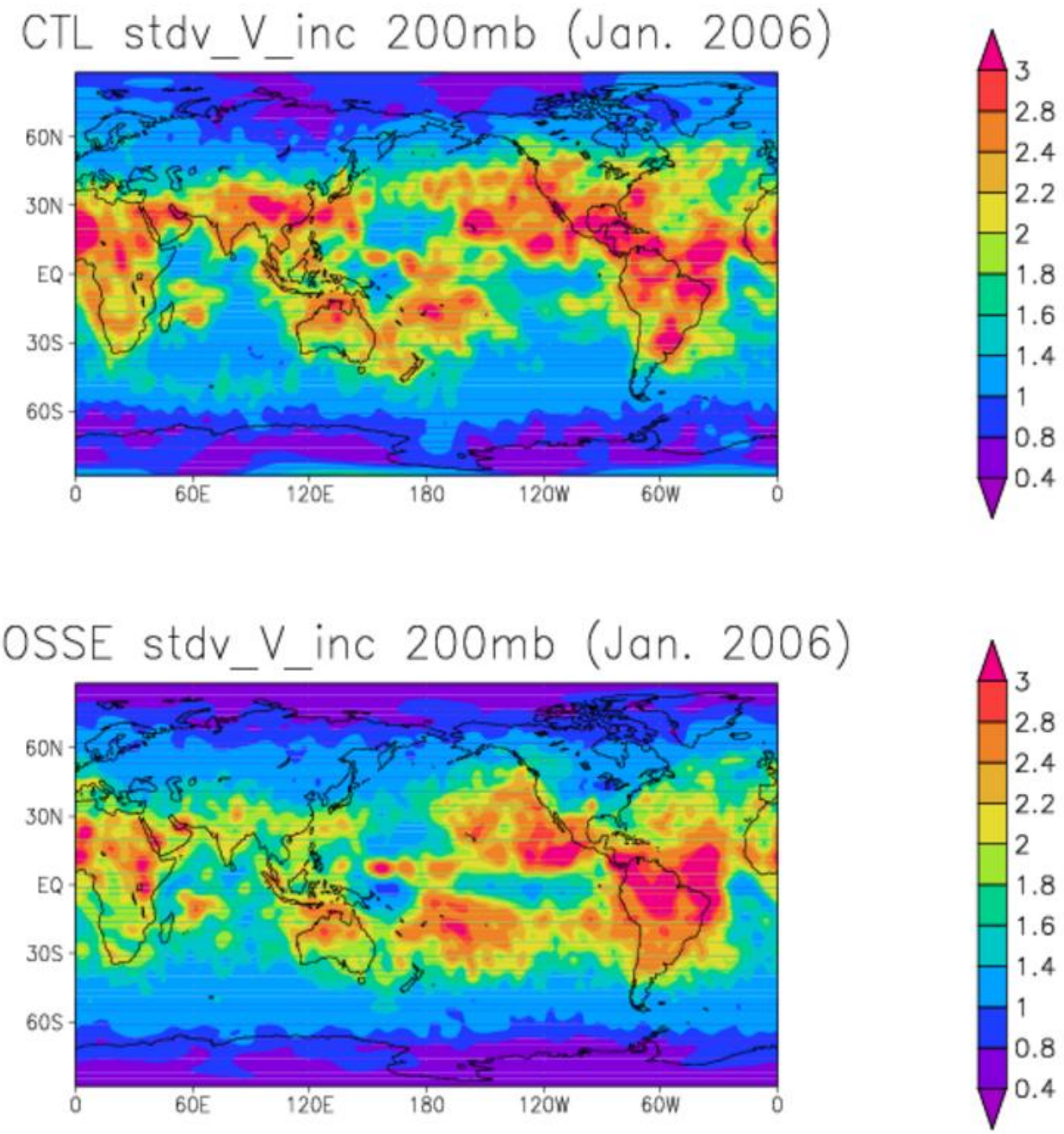

Standard Deviations O-F for AIRS Channels
2.5
2
1.5
1
0.5
0
3
31
56
67
81
92
102
114
126
172
193
221
NCEP Channel Number
Real
OSSE


Horizontal Correlations of RAOB T innovations N.H. Extra-tropics
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
100
180
260
340
420
500
580
660
740
820
900
Separation Distance (km)
200 hPa Real
200 hPa OSSE
500 hPa Real
500 hPa OSSE
850 hPa Real
850 hPa OSSE

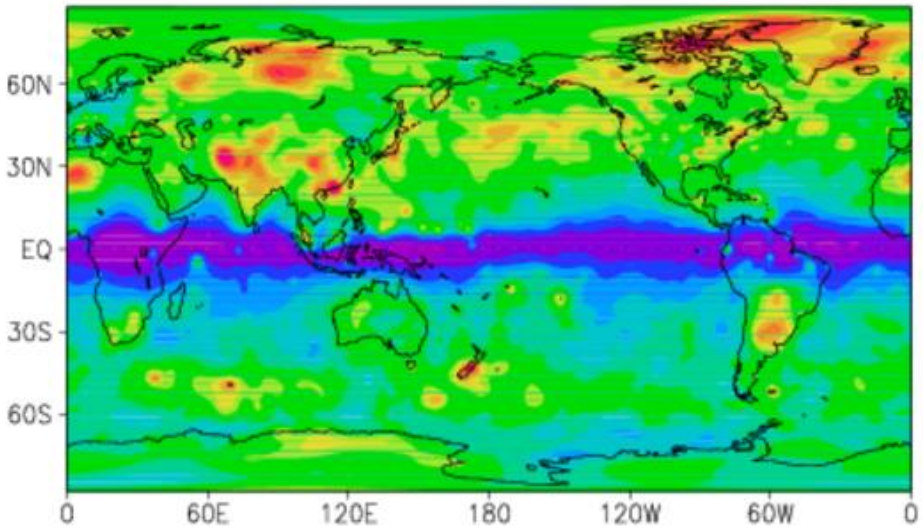

Horizontal Correlations of RAOB v innovations N.H. Extra-tropics
0.5
0.4
0.3
0.2
0.1
0
-0.1
100
180
260
340
420
500
580
660
740
820
900
Separation Distance (km)
200 hPa Real
200 hPa OSSE
500 hPa Real
500 hPa OSSE
850 hPa Real
850 hPa OSSE

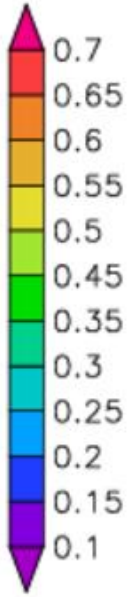

Horizontal Correlation GOES-IR v Wind N.H. Extra-Tropics
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
100
180
260
340
420
500
580
660
740
820
900
Separation Distance (km)
300 hPa Real
300 hPa OSSE
500 hPa Real
500 hPa OSSE
850 hPa Real
850 hPa OSSE


AMSU-A NOAA-15 Horizontal Correlations
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
100
180
260
340
420
500
580
660
740
820
900
Distance between observations (km)
Real 7
OSSE 7
Real 5
OSSE 5
Real 3
OSSE 3

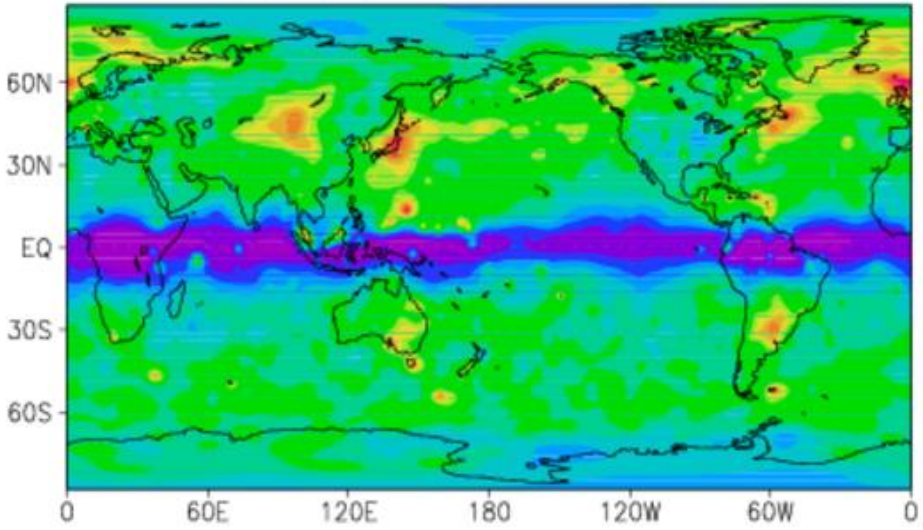

CTL stdv_V_inc 200mb (Jan. 2006)
60N
30N
EQ
30S
60S
0
60E
120E
180
120W
60W
0
3
2.8
2.4
2.2
2
1.8
1.6
1.4
1
0.8
0.4
OSSE stdv_V_inc 200mb (Jan. 2006)
60N
30N
EQ
30S
60S
0
60E
120E
180
120W
60W
0
3
2.8
2.4
2.2
2
1.8
1.6
1.4
1
0.8
0.4

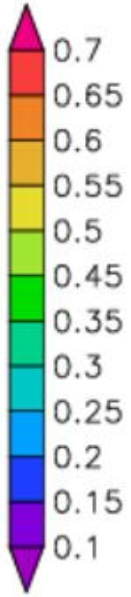
CTL stdv_Tv_inc 700mb (Jan. 2006)

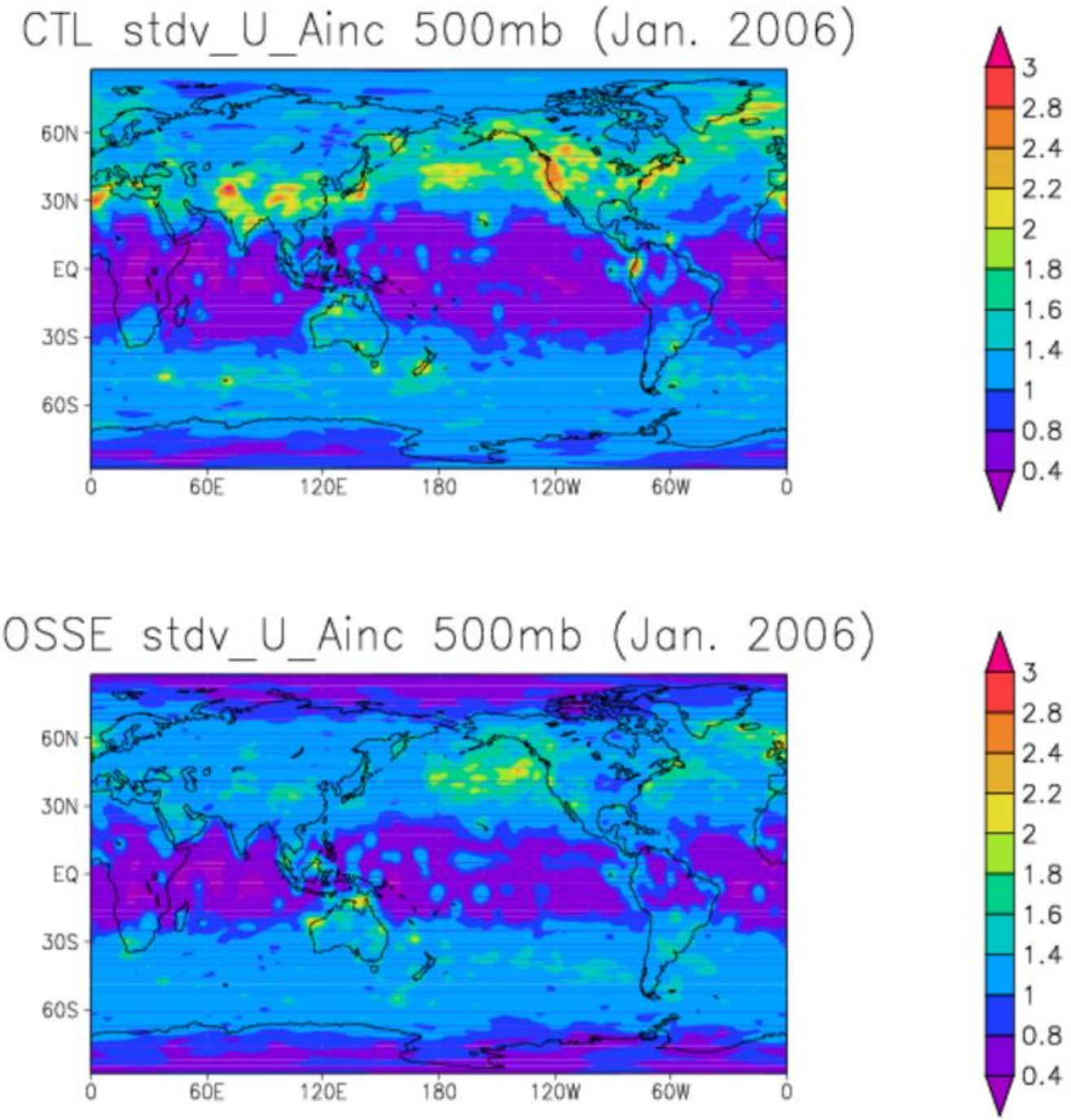


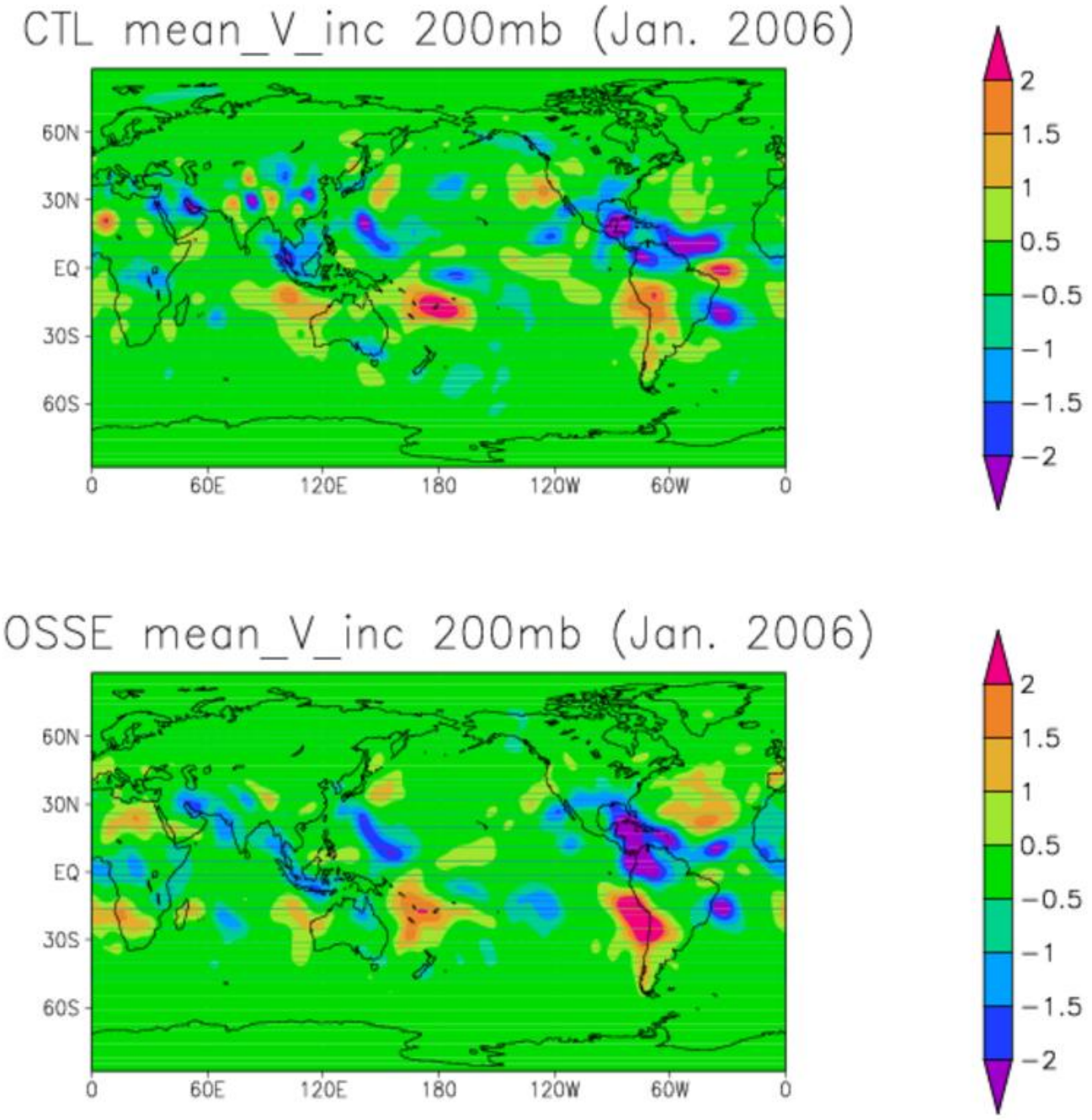


OSSE stdv_Tv_inc 700mb (Jan. 2006)

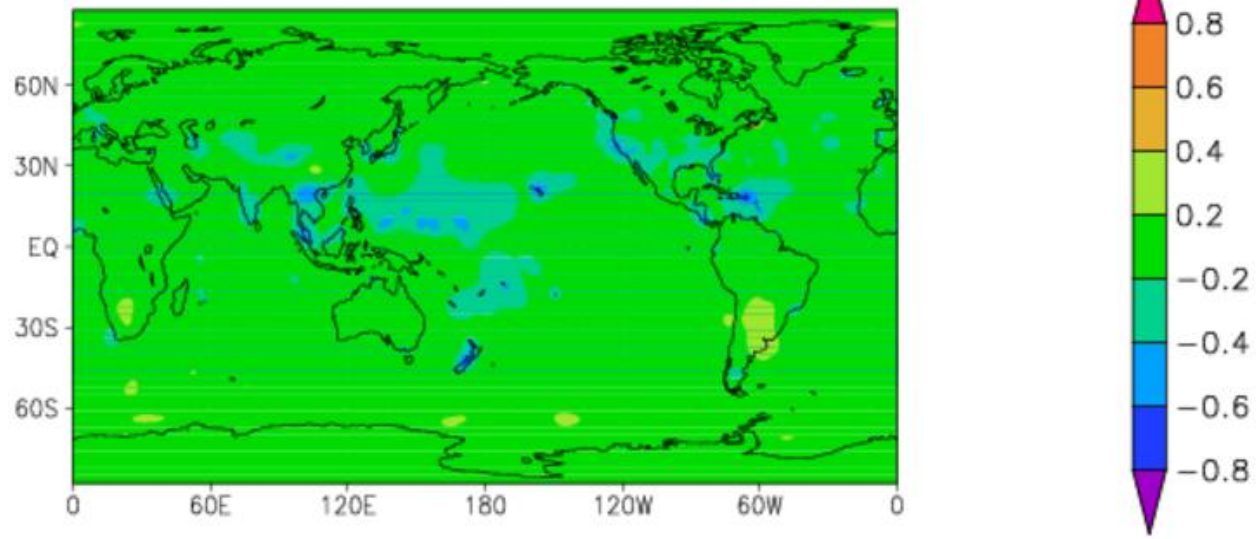




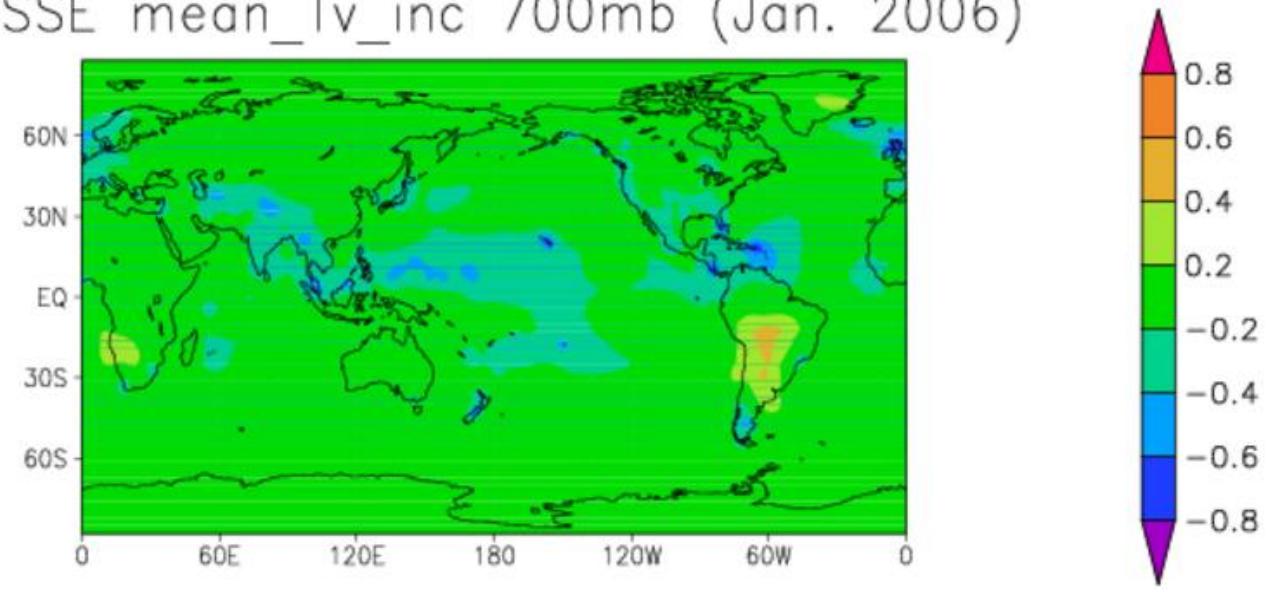

CTL stdv_U_Ainc 500mb (Jan. 2006)
60N
30N
EQ
30S
60S
0
60E
120E
180
120W
60W
0
3
2.8
2.4
2.2
2
1.8
1.6
1.4
1
0.8
0.4
OSSE stdv_U_Ainc 500mb (Jan. 2006)
60N
30N
EQ
30S
60S
0
60E
120E
180
120W
60W
0
3
2.8
2.4
2.2
2
1.8
1.6
1.4
1
0.8
0.4


CTL mean_V_inc 200mb (Jan. 2006)
60N
30N
EQ
30S
60S
0
60E
120E
180
120W
60W
0
2
1.5
1
0.5
−0.5
−1
−1.5
−2
OSSE mean_V_inc 200mb (Jan. 2006)
60N
30N
EQ
30S
60S
0
60E
120E
180
120W
60W
0
2
1.5
1
0.5
−0.5
−1
−1.5
−2

CTL mean_Tv_inc 700mb (Jan. 2006)



OSSE mean_Tv_inc 700mb (Jan. 2006)



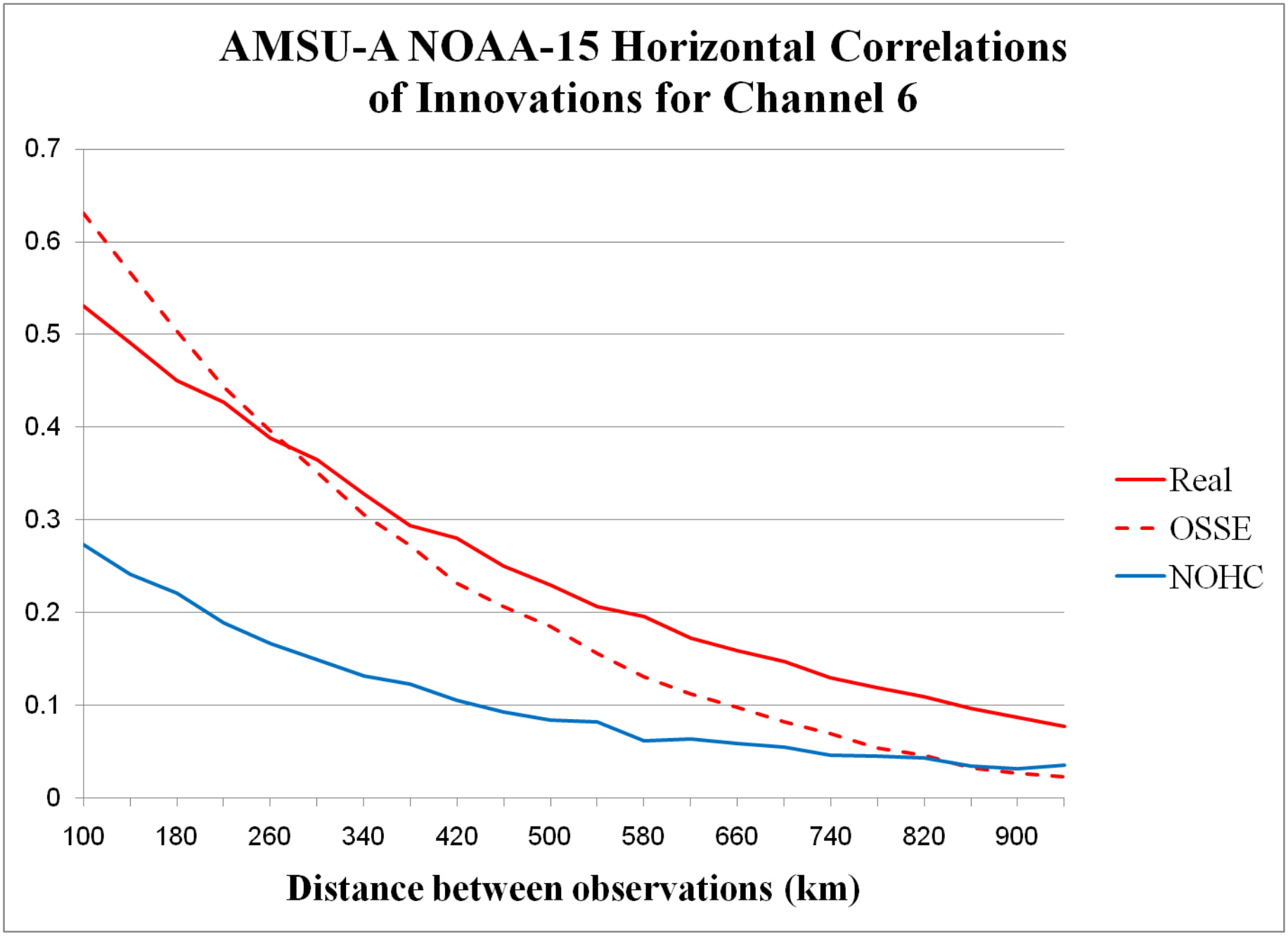
Consideration of the Analysis Equation

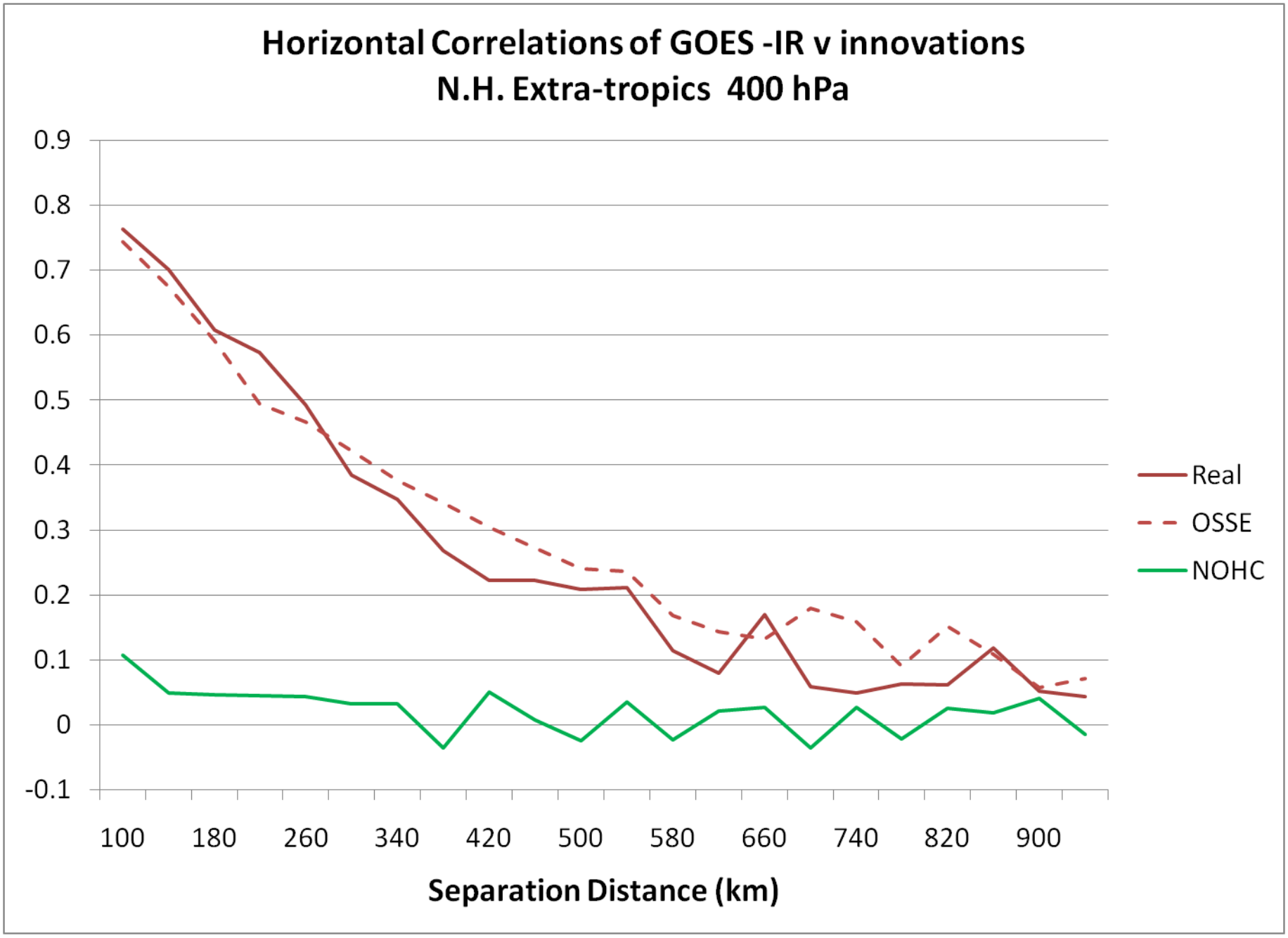
Assimilation of real observations:

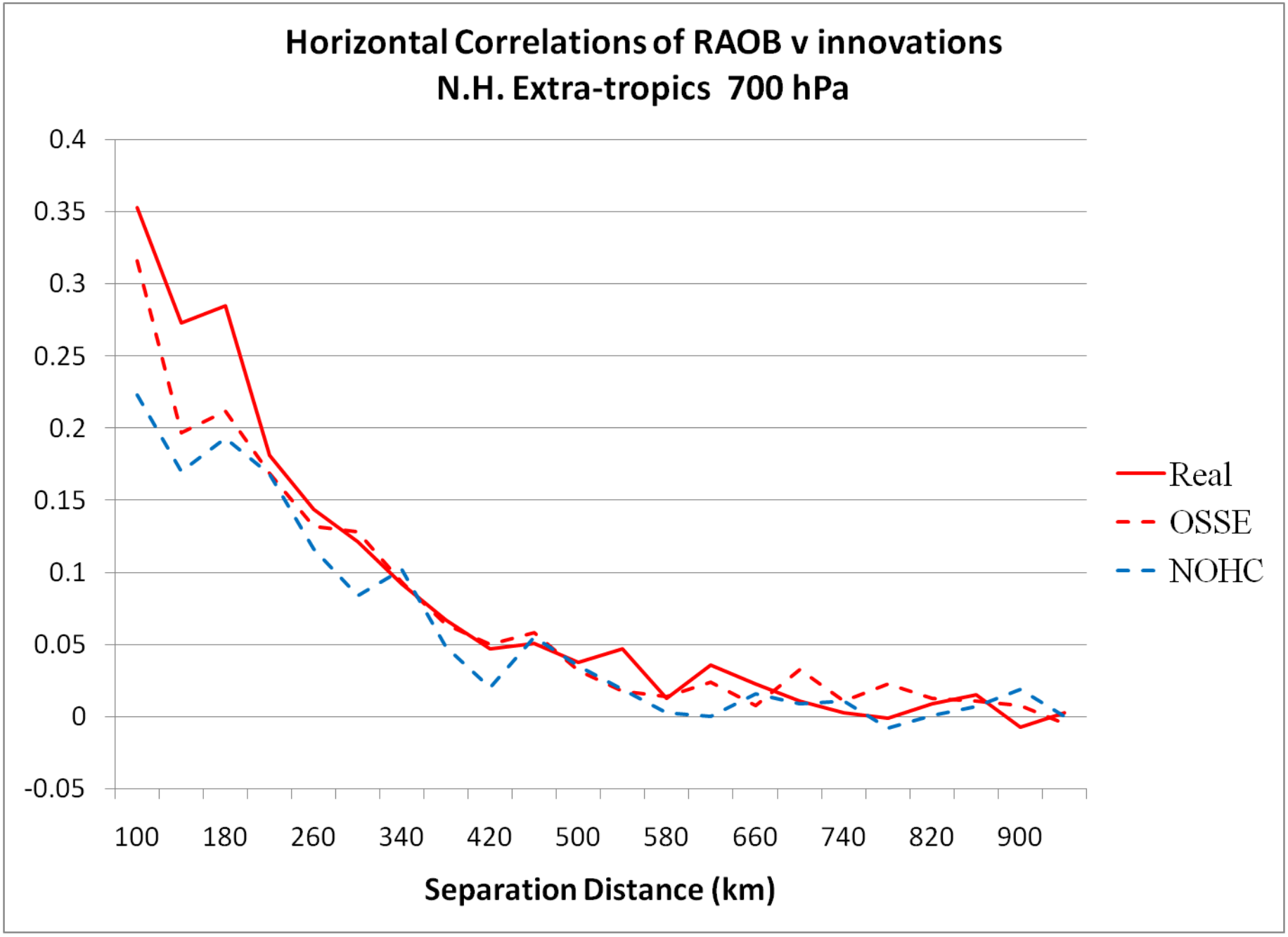
$$\mathbf{x}_a - \mathbf{x}_b = \mathbf{K}\left\{\mathbf{y} - H(\mathbf{x}_b)\right\}$$

Assimilation of simulated observations:

$$\mathbf{x}_a - \mathbf{x}_b = \mathbf{K}\left\{\left[\tilde{H}(\mathbf{z}) + \mathbf{e}\right] - H(\mathbf{x}_b)\right\}$$


AMSU-A NOAA-15 Horizontal Correlations of Innovations for Channel 6
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
100
180
260
340
420
500
580
660
740
820
900
Distance between observations (km)
Real
OSSE
NOHC


Horizontal Correlations of GOES -IR v innovations
N.H. Extra-tropics 400 hPa
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
100
180
260
340
420
500
580
660
740
820
900
Separation Distance (km)
Real
OSSE
NOHC


Horizontal Correlations of RAOB v innovations
N.H. Extra-tropics 700 hPa
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
100
180
260
340
420
500
580
660
740
820
900
Separation Distance (km)
Real
OSSE
NOHC

Towards Version 2

1. Simulate weather balloon flight through NR fields
2. Locate CTW where NR clouds are
3. Include MW channels affected by land
4. Further develop added error correlation model
5. Determine natural variability of validation metrics
6. Perform further validation of NR
7. Fine-tune simulation and error parameters
8. Compute additional metrics

Conclusions

1. It appears that the ECMWF Nature Run is useful for OSSEs.
2. It appears that the ECMWF and GMAO models sufficiently differ.
3. It appears that observations can be adequately simulated (no surprise).
4. It appears that some observation errors are horizontally correlated.
5. It appears that those errors must be modeled as such.
6. It appears that a valid OSSE system can be developed.
7. It appears that the simulated obs. plus errors already produced are useful.
8. Work is proceeding on:
   a. validation using forecast error metrics
   b. version 2 development
   c. simulation of dopplar wind lidar (Will McCarty)
   d. inclusion of aerosols in the NR (Arlindo Da Silva)